

Patent claims

1. A method for automatically detecting connectable surfaces in a technical system, in which
 - the system comprises a number of bodies,
 - a joining technology is prescribed which can be applied to produce a layer between in each case two bodies of the system,
 - a computerized design model of the system is given that, for each body of the system, comprises at least one surface belonging to the body,

having the steps of:

- producing finite elements for the surfaces,
 - selecting for each surface pair that consists of two different surfaces of the design model all the element pairs,
 - that consist of in each case one finite element of one surface, and of one finite element of the other surface of the surface pair,
 - whose spacing from one another is smaller than or equal to a prescribed upper bound,
 - and deciding for each selected element pair whether the two finite elements of the element pair can be connected by the joining technology,
 - a computer-evaluable decision criterion that compares the spacings, positions and/or orientations of the two finite elements with prescribed bounds being applied for taking the decision.
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2. The method as claimed in claim 1,
characterized in that
when selecting the element pairs of a surface pair
 - all the nodal points of the finite elements of the two surfaces are determined,
 - all the node pairs that consist in each case of one nodal point of one surface and one nodal point of the other surface are determined,
 - the spacing between the two nodal points of the node pair is calculated for each node pair,
 - those node pairs are selected whose nodal points have a spacing that is smaller than or equal to the bound, and
 - each element pair is determined whose one finite element has one nodal point of a selected node pair as a nodal point, and whose other finite element has the other nodal point of the same node pair as a nodal point, and

- determined element pairs are used as selected element pairs.

3. The method as claimed in claim 2,
characterized in that

- each determined element pair is preselected whenever each nodal point of one finite element of the element pair has a spacing from at least one nodal point of the other finite element that is smaller than or equal to a prescribed upper bound,
- each preselected element pair is selected whenever the spacing between the two finite elements of the element pair is smaller than or equal to the upper bound,
- and a decision is made for each non-preselected element pair that the two finite elements of the element pair are not connectable.

4. The method as claimed in claim 2,
characterized in that

- each determined element pair is preselected whenever each nodal point of one finite element of the element pair has a spacing from all nodal points of the other finite element that is smaller than or equal to a prescribed upper bound,
- each preselected element pair is selected whenever the spacing between the two finite elements of the element pair is smaller than or equal to the upper bound,
- and a decision is made for each non-preselected element pair that the two finite elements of the element pair are not connectable.

5. The method as claimed in one of claims 1 to 4,
characterized in that,

- when selecting the element pairs
- whenever the spacing between the two finite elements of an element pair is greater than a prescribed bound
- the element pair is not selected.

6. The method as claimed in one of claims 1 to 5,
characterized in that

when comparing the spacing of two finite elements of an element pair with a prescribed upper and/or lower bound at least one of the following sequences is carried out:

- determining the point of intersection of the two diagonals of one finite element,

- determining the point of intersection of the two diagonals of the other finite element,
- determining the spacing between the two points of intersection,
- erecting a normal to one finite element of the element pair, determining the foot point of the normal in the finite element, determining the point of intersection of the normal with the other finite element, comparing the spacing between foot point and point of intersection with a prescribed upper and/or lower bound,
- erecting a normal to one finite element and a normal to the other finite element of the element pair, determining the sum vector of the two normals, determining the point of intersection of a straight line in the direction of the sum vector with the other finite element, calculating the spacing between point of intersection of the straight line with one finite element and point of intersection of the straight line with the other finite element, comparing the spacing with a prescribed upper and/or lower bound,
- for each nodal point of one finite element of the pair, erecting a normal through the nodal point on the finite element, determining the point of intersection of the normal with the other finite element, comparing the spacing between nodal point and point of intersection with a prescribed upper and/or lower bound.

7. The method as claimed in one of claims 5 to 6, characterized in that when taking a decision for a selected element pair at least one of the following tests is carried out:

- testing if the finite elements of the element pair belong to surfaces of different bodies,
- determining the angle between the two finite elements of the element pair and comparing the angle with a prescribed upper bound,
- projecting one finite element of the element pair along a projection vector and testing whether the projected finite element overlaps with the other finite element or not,
- determining the midpoints of the two finite elements of the element pair, projecting one finite element along a projection vector, determining the spacing between the midpoint of the projected finite element and the midpoint of the other finite element, comparing the spacing with a prescribed upper bound,
- determining the midpoints of the two finite elements of the element pair, projecting one finite element along a projection vector, determining the spacing between the midpoint of the projected finite element and the midpoint of the other finite element, determining the length of the longest edge of the two finite elements of the pair, comparing the quotient of spacing and longest edge length with a prescribed upper bound.

8. The method as claimed in claim 7,
characterized in that

- the projection vector is generated as sum vector from a normal to one finite element, and a normal of equal length to the other finite element,
- and the angle between the two finite elements is generated as angle between a normal to one finite element and a normal to the other finite element.

9. The method as claimed in one of claims 1 to 8,
characterized in that

- the prescribed bounds depend on at least one of the following parameters:
- a technical parameter of the prescribed joining technology,
- the nature of a surface of a body,
- a technical parameter of a material provided for producing a body,
- a stipulation valid for all the bodies of the system.

10. The method as claimed in one of claims 1 to 9,
characterized in that

- the prescribed joining technology comprises one of the following methods:
- layer,
- inserting a spacing layer.

11. The method as claimed in one of claims 1 to 10,
characterized in that

various possible joining technologies are prescribed,
for each possible joining technology,

- a decision criterion is prescribed that compares the positions and/or orientations of two finite elements with prescribed bounds dependent on the joining technology,
- and an evaluation of the joining technology are prescribed,

those pairs of finite elements that can be connected by the joining technology are determined for each joining technology,

the decision criterion prescribed for this joining technology being applied to the finite elements of the pair during the determination,

an evaluation of the joining technology with reference to the system is determined by applying an evaluation function that calculated from the prescribed evaluation of the joining technology and the element pairs that can be connected with the aid of the joining technology, that joining technology is selected for which the highest evaluation was determined with reference to the system, and the further finite elements are generated in the interspaces that are delimited by those element pairs that can be connected with the aid of the selected joining technology.

12. The method as claimed in one claims 1 to 11, characterized in that further finite elements are automatically generated in the interspaces that are delimited by the finite elements detected as being connectable.

13. The method as claimed in claim 12, characterized in that

- the further finite elements are volume elements in the interspaces,
- the volume elements are generated in such a way that all the interspaces are fully meshed by volume elements,
- and the meshing is produced by using geometric information relating to the interspaces and stipulations for the meshing.

14. The method as claimed in claim 12, characterized in that at least one further finite element in an interspace is a planar element that is perpendicular to an adjoining surface of the design model.

15. The method as claimed in one of claims 12 to 14, characterized in that

- there is set up, in accordance with the finite element method, a system of equations in which occurring as unknowns are the values that are assumed by a spatially variable physical quantity at the nodal points of the generated finite elements,
- and the values of the quantity at the nodal points are determined by a numerical solution of the system of equations.

16. The method as claimed in claim 15,
characterized in that

for a set of nodal points of further finite elements in the interspaces,

- there are respectively determined a closest surface of the design model, a closest finite element of this surface, and a closest point on this finite element,
- and equations for physical relationships between
 - the values that the physical quantity assumes in the set of nodal points,
 - and the values that the physical quantity at the closest points, determined for the set, of the surfaces

is generated and used when setting up the system of equations.

17. The method as claimed in claim 15 or claim 16,
characterized in that

for at least one nodal point of the set,

- a function is generated for a physical relationship between the value that the physical quantity assumes at the closest point and the values that this quantity assumes at the nodal points of the closest finite element,
- and the value of the physical quantity at the determined point is eliminated by using the function when setting up the system of equations.

18. The method as claimed in one of claims 1 to 17,
characterized in that

the total volume in the interspaces between all the connectable element pairs is determined.

19. A computer program product that can be loaded directly into the internal memory of a computer and comprises sections of software with the aid of which a method as claimed in one of claims 1 to 18 can be executed when the product runs on a computer.

20. A computer program product that is stored on a computer readable medium and that has computer readable program means that prompt the computer to execute a method as claimed in one of claims 1 to 18.